Topological defects in vibrated monolayers of granular rods

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We analyse liquid-crystalline ordering in vertically vibrated, quasi-two-dimensional monolayers of rods lying on a horizontal circular cavity, which project on the plate as rectangles. As a result of inelastic collisions involving rods and the cavity walls, energy is transferred to the horizontal plane and the monolayer exhibits some characteristics typical of thermally excited equilibrium systems. In particular, after an initial transient regime, low aspect (length-to-breadth) ratio particles, at high packing fractions, frequently form globally tetratic arrangements with C_4 symmetry [1]. This symmetry, which is incompatible with the circular geometry of the cavity, is restored by the creation of four point defects with a total topological charge of $+4$. The defects show a slow dynamics which we investigate [2].

First, we compare the behaviour of the granular monolayer with equilibrium Monte Carlo simulations of an equivalent system of hard rectangles. As expected, the equilibrium system also exhibits tetratic configurations with four point defects in a square arrangement (Fig. 1). In both systems defects stay close to the surface, which points to the existence of repulsive effective interactions between the defects, mediated by the tetratic medium.

To study the nature of these interactions, we also measure the interdefect distance distribution in the experiment (Fig. 2), and compare it with a simple model where four point particles with logarithmic repulsive interactions are simulated in the cavity using Brownian dynamics. From this comparison we extract a stiffness coefficient for the tetratic medium, which turns out to be of the same order as corresponding elastic constants of tetratic phases in equilibrium systems, thus establishing clear similarities between the elastic properties of this steady-state, dissipative vibrated system, and the corresponding system in thermal equilibrium.

We also point out the differences found between the two systems, which can be ascribed to the nonequilibrium nature of fluctuations in the excited granular monolayer. On the one hand, local excitations of regions with smectic order between defects in the experiment, not present in the equilibrium simulations, tend to make interactions between nearest defects stiffer and renormalise the elastic constant. These regions cause anisotropic defect interactions. Also, particle orientations near the cavity wall are different, which affects the preferred distance between the wall and the defects.

Finally, nonequilibrium simulations of rods regarded as active particles are presented. These simulations show that activity, together with excluded-volume interactions and frustration due to the confining geometry all compete to give a complex behaviour which captures some features of the real experiment on granular rods.

[1] M. González-Pinto, F. Borondo, Y. Martínez-Ratón, and E. Velasco, Clustering in vibrated monolayers of granular rods, Soft Matter **13**, 2571 (2017).

[2] Defects in vertically vibrated monolayers of cylinders, M. González-Pinto, J. Renner, D. de las Heras, A. Díaz de Armas, Y. Martínez-Ratón, and E. Velasco, (to be published).

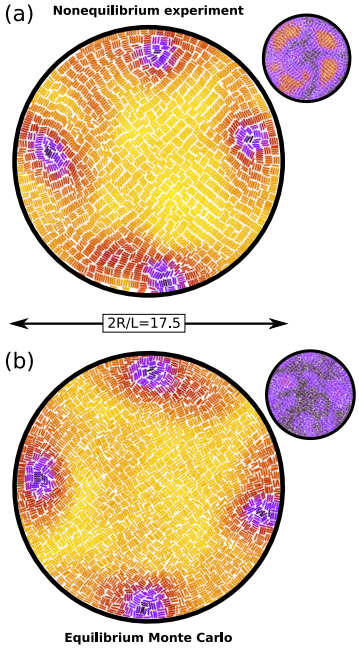

Fig. 1. Colour map of tetratic order parameter (big images) for particular configurations. Upper panel: experiment. Lower panel: Monte Carlo simulation. Particles are mostly arranged in a global tetratic configuration except in four defected regions where the tetratic order parameter is depressed. Colour maps for the uniaxial nematic order parameters are also shown (small images). Smectic regions are not excited in the MC simulations, but they frequently appear in the experiment.

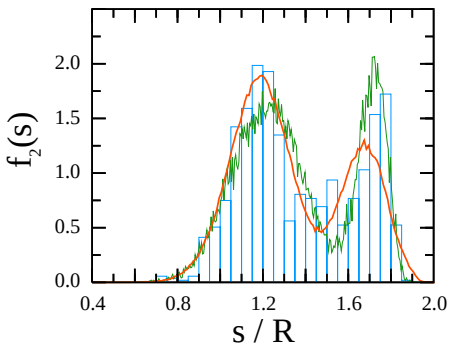

Fig. 2. Defect distance distribution in the experiment (histogram), the MC simulation (red curve) and the Langevin simulation (green noisy curve).